

Management of Nitrogen Fertilization in Sudangrass for Optimum Production, Forage Quality and Environmental Protection

Project Leader

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Objectives

- 1) To determine the optimum economic yield and forage quality response of sudangrass to N fertilizers in the low Desert environment.
- 2) To develop rapid diagnostic test to monitor N content in sudangrass to aid in the in-season management of N fertilization.
- 3) Effectively communicate results of these studies to growers and the general public.

Summary

Field Studies were conducted in 1997 and 1998 at El Centro and Blythe, CA to examine the influence of N fertilizers on yield and quality response in Sudangrass (*Sorghum bicolor*). Seven N rate treatments (applied as ammonium nitrate) were established in a randomized block design at these two locations. Treatments were Non-fertilized control, and 35, 70, 105, 140 and 210 lb N/acre applied each growth period (top rate represents up to 840 lb N/acre over the season). There was considerable variation between sites in their responsiveness to N fertilizers. Sites varied from no significant response at any N rate, to yield response to the highest rate per cutting. Most evidence indicates little chance of yield response at N applications greater than 70 lbs/acre per growth period (280 lbs N/year) averaged across sites. Considerable attention to residual N from previous cropping history may help in management of N. Most sites indicated lower response (or lack of response) in the first harvest, with a greater response in later cuttings, indicating that applications at the first growth period should be minimized to account for residual soil N. Nitrate concentrations in sudangrass forage were increased significantly in most cases by N applications, but fertilizers were not the only cause of high nitrates. Nitrate-specific electrode (Cardy Meter) readings explained 67% of the variation in plant nitrates in the samples analyzed to date, but the levels show a distinct negative bias, and some data sets showed a poor relationship between Cardy meter readings and plant nitrates. Results from these studies were presented at field days, published in the California Plant & Soil Conference Proceedings, and reported at the FREP Conference. Future work should address issues of the causes of nitrate concentrations in sudangrass forage, and standardize nitrate methods with laboratories.

Work Description

NOTE: These tasks are listed for one year and will be repeated in the second year.

Determining optimum economic yield and forage quality response of sudangrass to N fertilizers. Yield responses to N fertilization were estimated at 2 sites: El Centro and Blythe, under a 4 cut system, which is likely best suited to the targeted export market. Nitrogen applications were allocated equally to each growth period across the season. Ammonium nitrate was the fertilizer source. 'Piper', a well-adapted sudangrass variety will be used. The treatments are designed to incorporate both deficient and excessive application rates:

1. Non-Fertilized controls
2. N applied at 35 lb N/acre at each growth period (140 lb N/acre total)

3. N applied at 75 lb N/acre at each growth period (300 lb N/acre total)
4. N applied at 120 lb N/acre at each growth period (480 lb N/acre total)
5. N applied at 170 lb N/acre at each growth period (680 lb N/acre total)
6. N applied at 225 lb N/acre at each growth period (900 lb N/acre total)
7. N applied at 285 lb N/acre at each growth period (1,140 lb N/acre total)

The experimental design will be a randomized complete block with 4 replicates. The rates at each harvest were constant across locations, and adequately described the most important portions of the response surface. Plots will be planted with a grain drill (6" row spacing), and will be 10' wide X 30' long, which is sufficient to prevent border effects from neighboring plots. Sudangrass yield will be measured using a flail-type harvester and dry matter samples taken at each harvest for yield determination. This task will result in data that will help guide recommendations for application rates to maximize yield and forage quality in the Low Desert environment.

Presentation on sudangrass and on research objectives to growers at a March Field Day. Meet to finalize and discuss experimental plans. Product: Finalized plans for experimentation. (Completed 3/30/97, time of alfalfa field day).

Preparation of field sites through primary tillage, land leveling, and development of an appropriate seedbed. Each block of the field sites will be sampled to a depth of 4 feet (increments of 6") to determine initial N and soil fertility. Product: baseline information on site. (Completed 4/1)

Planting of sudangrass, establish plot boundaries, and make initial application of ammonia nitrate. A medium to high plant density (150 lbs/acre seed) will be used, which encourages a small stem diameter, an important market consideration (commonly practiced by growers). All fertilizers applied by hand. Product: establishment of experiment. (Completed 4/15)

Setting of irrigation schedule according to recommendations of irrigation specialist and common practices for the Low Desert, using the CIMIS model ET and appropriate crop coefficient to arrive at crop water-use. The irrigation schedule will help determine the harvest schedule, and be repeated consistently throughout the season. The management of water was a crucial aspect of this experiment, since deficient level may induce nitrate accumulation in plants, and excessive levels may contribute to groundwater contamination. The irrigation schedule was determined by the CIMIS process, with due consideration of common grower practices. Product: Proper management of irrigation water. (Completed 9/30)

Sudangrass was harvested with a flail-type harvester at 4" height. Timing of sudangrass harvests will be determined by plant growth characteristics, primarily plant height. In addition, ten, randomly selected whole plants were harvested for dry matter determination and forage quality. Samples will be taken from the center of plots and later dried in forced-air oven at 55° C. This task will be performed 4 times per season at each site at about 45 day intervals. Product: Yield data & plant samples. (Completed 10/30)

A single sample/plot (task 1.5) will be ground using a Wiley Mill or similar grinder with a 1 mm screen. Approximately 224 samples/year will be taken (112/site). Nitrate and total N will be measured using standard wet chemistry methods, and ADF, NDF and CP content will be

measured using near infrared spectroscopy (NIRS) at UC Davis. An appropriate number of wet chemistry analyses will be conducted to support the NIRS calibration. (Completed 11/1).

Subsequent N fertilizer applications will be made on the appropriate plots 7 days after each harvest. (Completed September both years)

Analysis of data. This task will be performed in Davis and Blythe, and be completed approximately 3/1 following year.

Develop rapid diagnostic tests to monitor N content in sudangrass to aid in-season management of N fertilization. Although we have divided N applications equally throughout the season in this study (a common grower practice), crop-use or N requirements may not match this practice. Tools to aid in decision-making for N application could be utilized during or before each growth period to guide application decisions. If a producer can monitor the growing crop, timely decisions to increase or decrease, or to omit N applications can be made. A Cardy meter will be purchased for each site with appropriate support materials. The relationship between these readings and plant measurements will be examined. The product of this research will be the possible discovery of reliable relationships between Cardy-meter readings, NIR spectra, and total crop N concentration, nitrate concentration, and yield and quality response of sudangrass.

Cardy-meter sampling. Ten-fifteen randomly-selected sudangrass stems were cut 4 inches from the soil. Plant sap was extracted from a section of the stem at 4"-12" height using established protocol for the Cardy-meters, and a reading recorded for each plot. This sample was taken 14 days after the first irrigation of each growth period, and again at harvest (the same sample as in Subtask 1.5-1.6 will be used at harvest). Product: Cardy-meter data on plants during growth and at harvest. (Completed 9/15).

The same 10-15 randomly-selected plants was retained, dried, ground and analyzed for total N content and nitrate (14-day sample), and for ADF, NDF, CP, total N, and nitrate at harvest. This work was done at the DANR lab, Davis. NIRS spectra was taken on these samples and a calibration developed to predict these parameters. For the nitrates and total N, all samples will be run using wet chemistry. For the other values (ADF, DM), wet chemistry values was generated on selected samples using appropriate selection protocols for NIRS. It is expected that the NIRS calibration can be used as a tool to help manage N fertilization and nitrate, as well as the Cardy-meter technique. Product: Forage quality and N data on plant samples. (Completed 1/1 last year of study)

Data analysis. Data was analyzed in both Blythe and Davis. Regression analysis will be applied to discover the predictability of either the cardy meter or NIRS technique for N management and for nitrate prediction. Product: Analysis of variance & regression of raw data. (Completed 3/1)

Communicate results of these studies to growers and the general public.

Scientific research results become valuable only when they are communicated to the individuals in decision-making positions, so that practices may be impacted. This was done through field days, grower meetings, fact sheets, newsletters, and peer-reviewed publications. The results of

this task will be a better understanding among growers, PCAs and the general public about the nitrogen requirements and methods to monitor N fertilizer applications in sudangrass.

A special field day/workshop was to be held in August or September of each year which will allow growers to view the plots and to assist growers in the management of N. This workshop would have had the purpose of communicating research results, discuss N management, and to train growers in the use of Cardy meters, NIRS, or other methods of N management, if they appear promising. Note, due the loss of the cooperator (Robert Kallenbach at Blythe), we held several lower-key events at Blythe and El Centro to help growers understand the importance of N fertilization of sudangrass.

Grower meetings were held in Blythe (Progressive Farmer's Group) over the summer to report and discuss the progress of the trial and to communicate effective N management methods. This was held in October, both years.

Newsletters from El Centro and Blythe will report on the establishment and progress of the trial during the season. Final results will be featured in those newsletters, as well as other outlets. (Completed 12/30)

Field Days were held in El Centro and in Blythe in March of each year to communicate plans, and to communicate final results. The timing of the field day coincided with the annual alfalfa/small grain field days, which have been gaining strength and acceptance at both El Centro and Blythe over the past years. Product: field day and proceedings (Completed 3/30)

The PIs will author a DANR publication at the completion of the study which will summarize the results and help prepare the data for publication in a peer-reviewed journal. Product: DANR publication on N in sudangrass (this is not completed as of this writing)

Project Evaluation

The PI(s) had intended to develop a questionnaire for growers that could help evaluate the efficacy of the study. This would ascertain whether growers were adapting the practices recommended by the research. A full evaluation of this project has not been completed. The PI has been in touch with a number of growers and answered a number of phone calls about the issue of N application on sudangrass, and made available reports and data to the clientele. Many have found this information to be of use.

Results, Discussion, and Conclusions. (See completed article below).

Outreach Activities

3/30/97 'N Management in Sudangrass' Alfalfa & Forage Field Day. Blythe CA. Approximately 70 attending.

9/15/97 'N Experiments with Sudangrass' Fall Alfalfa Field Day, Blythe, CA.
Approximately 60 attending

4/14/98 'Sudangrass Experiments' Spring Alfalfa Field Day, El Centro, CA.
Approximately 75 attending.

11/30/99 'Influence of N Fertilizers on Sudangrass Yield and Quality' by Dan
Putnam, R. Meyer, and R. Kallenbach. California FREP Conference Proceedings

Influence of N Fertilizers on Sudangrass Yield and Quality

by Dan Putnam, Roland D. Meyer, and R. Kallenbach¹

INTRODUCTION

Sudangrass hay (*Sorghum sudanense* (Piper) Stapf) was grown on over 100,000 acres in 1997 and contributed 53 million dollars to the agricultural economy of California. Most of California's sudangrass is grown in the Imperial and Palo Verde Valleys of southern part of the state. In addition, small acreage of sudangrass has been used as summer-grown forage in California in dairy regions. Statewide average yields are 5.5 tons/acre. Acreage in the desert has grown significantly due to the rise in exports to Japan, as well as overall increased domestic forage demand. Although sudangrass export markets declined significantly in 1998 and early 1999, there is continued interest in sudangrass for exports, as well as for California's rapidly expanding cattle population (dairy and beef). Sudangrass is often double- or triple-crop with small grain forage or corn California's Central Valley.

Large quantities of N fertilizers are commonly used in the production of sudangrass hay, at rates varying from 150 to over 800 lb. N/acre. Typical system in the desert is a 3 to 4 cut system when the crop is planted in early summer (April). However, there has been very little research data to guide growers in the determination of optimum N fertility management for sudangrass in California. Insufficient N has been identified as a common yield-limiting factor. In addition, excessive application rates applied to Sudangrass may exacerbate groundwater nitrate problems or nitrate toxicity in cattle feed.

This research was conducted to determine the yield and forage quality (particularly nitrate concentration) response of sudangrass to N fertilizers in the Low Desert environment, quantify the effects of N application rates on the potential for nitrate accumulation. We also wanted to develop rapid diagnostic tests (using Cardy meters and near infrared spectrophotometry- NIRS) to monitor N content in the forage. Nitrogen rate studies were conducted in Blythe and El Centro, California. This is a preliminary report of the yield and forage quality results of this study to date, with other aspects of the study to be reported later.

PREVIOUS STUDIES

Sudangrass responds remarkably to nitrogen fertilizers, but there is little data to guide nitrogen recommendations for California growers, especially in desert regions. An

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informal survey of growers in the Low Desert region indicates that nitrogen rates vary from 150 to over 800 lb.

N/acre annually. These rates seem excessive in comparison with recommended rates in other regions, but our growing season is longer, we have warmer temperatures, we harvest 4 times compared with 1-2, and yields are often double those of other regions.

Researchers in Oklahoma, Alabama, and Australia found that sudangrass yields are maximized when fertilized with about 250-350 lb. N/acre (Harms and Tucker, 1975; Long, 1981; Muldoon, 1985). In these studies, fertilizer rates greater than 350 lb. N/acre either reduced yields, increased nitrogen losses through leaching, or both. It is not likely that these results are highly relevant to our conditions, given the tremendous differences in seasonal yield. It is probable that larger nitrogen applications are appropriate for the warmer conditions and longer growing season of the Low Desert, but there is little scientific basis for this assumption.

One method for calculating nitrogen recommendations is to estimate crop removal, adjusted for fertilizer N-use efficiency (50-80%). Sudangrass yields in the low desert averaged 7.1 tons per acre in 1993 and 1994 (Imperial County Agricultural Commissioner, 1995). Based on a nitrogen concentration of 1.75% of dry weight, annual crop removal for an average crop would be about 249 lb. N/acre. Adjusting for fertilizer efficiency, this might be equal to over 350 lbs. N/acre applied fertilizer/ year.

However, many producers and crop consultants are uncomfortable basing N rates based solely on uptake. Several factors are unaccounted for by this method including: contributions of residual nitrogen from previous crops, timing of application, nitrogen lost

Figure 1. Yield response to N in 1956 study, El Centro, CA (Worker, 1976)

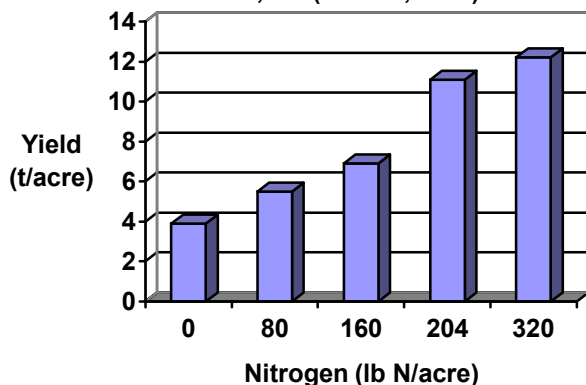
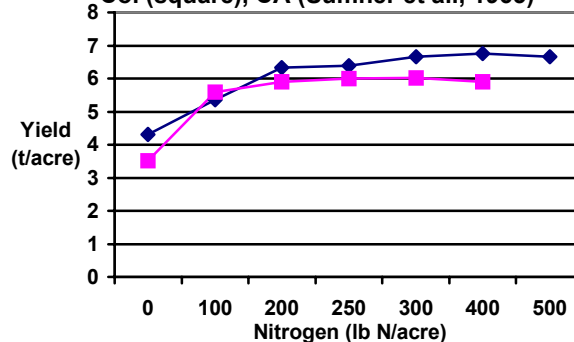


Figure 2. Yield response to N in 1963 CA Study at Davis (diamond) and Kings Co. (square), CA (Sumner et al., 1965)



to denitrification, nitrogen contributions from organic matter, leached nitrogen and application inefficiencies. Methods should reflect more closely plant requirements and ability of the soil to provide N (Ulrich, 1983). At present, Low Desert producers and crop consultants rely on anecdotal or trial-and-error protocols to fertilize sudangrass.

Previous California Studies. A one-year study was conducted in 1956 at the Desert Research and Extension Center, and reported by Worker (1976) (Figure 1). This indicated a large yield response of 'Piper' sudangrass to applied N. A 1963 study was conducted at UC Davis and in Kings County, CA which examined N-rate influence on sudangrass (Sumner, et al., 1965). Both studies showed dramatic effects of N fertilizers on yield. Sumner et al. suggested that 200 lbs/a N is optimum as a split application when pasturing or greenchopping irrigated Piper sudangrass (their study was conducted with a 5-cut system, not typical for export hay). High nitrate levels (>23,000 PPM) in the forage were observed with high N application rates (Sumner, et al, 1965).

Pratt et al. (1976) conducted a study in the Chino-Corona basin near Los Angeles on the effects of animal manure on nitrates in sudangrass and barley. Plant maturity, irrigation, as well as time of harvest had an effect on nitrate accumulation. They reported sudangrass nitrate concentrations in excess of 5000 PPM NO₃-when available soil nitrogen was 480 kg/ha. When feeds contain nitrate levels in excess of 2100 PPM, reduced growth rates, or even death of livestock can result (NRC, 1984). Nitrogen may also affect forage quality. There is evidence that protein and/or digestibility may improve with increased N rates (Sumner et al., 1965;Fribourg, 1974).

METHODS & MATERIALS

Field plots of sudangrass were established in 1997 and again in 1998 at the UC Desert Research and Extension Center in El Centro and on a grower's field in Blythe, CA. Seven N rate treatments (applied as ammonium nitrate) were established in a randomized block design at these two locations:

1. Non-Fertilized controls
2. N applied at 35 LB N/acre at each growth period
3. N applied at 70 LB N/acre at each growth period
4. N applied at 105 LB N/acre at each growth period
5. N applied at 140 LB N/acre at each growth period
6. N applied at 210 LB N/acre at each growth period

Fertilizers at rates above 35 lb./acre were applied in split applications during each growth period. One application was initially after harvest, just before irrigation, and the other at the time of a second irrigation. These treatments were meant to correspond to water-applications of N fertilizers, which are very common in Desert Regions. Fertilizers were applied as NH₄NO₃. Data from these trials were collected for forage yield, dry matter, and forage quality. Chlorophyll-meter readings (for total chlorophyll concentration) and Cardy meter readings (which measure nitrate in the stems) were taken at each harvest. Cardy meter readings were taken on the stem material, and chlorophyll readings were taken at mid-leaf, avoiding the midrib. Additional data were taken which will not be discussed in this report.

RESULTS

Four harvests were measured on these plots in 1997 and three harvests were measured in 1998 from both Blythe and El Centro.

The Blythe data from 1997 indicated a significant ($P < 0.05$) effect of N at all harvests. The first cutting showed increased yields only at the 35 lb./a rate. At the time of the second and subsequent cuttings, yields responded significantly at the 70 lb. N/acre rate, and seasonal yields showed little response past 70 lbs/a N applied at each cutting (280 lbs total).

The El Centro site in 1997 exhibited higher field variation due to unknown factors, and the response of sudangrass yield to the N treatments was non-significant at each harvest and in the seasonal total. Highest yields were observed at the El Centro site in 1997 (Figure 7).

The cutting-by cutting data from Blythe, 1997 were typical of the pattern of yield response in 1998 at both sites (data not shown), with little response at the first cutting, and more intense yield response in subsequent cuttings. The seasonal 1998 totals (Figure 7) indicated a yield response up to 70 lbs/acre at El Centro, and up to 210 lbs/acre in Blythe.

N increased Sudangrass nitrate concentration in all of the samples that have been analyzed to date (Figure 8, 9 and 10). A wide range of nitrate levels was measured at the different cuttings and environments, ranging from 100s of parts per million to >20,000 PPM (lab values). For example, the last cutting of 1997 at Blythe was 1,000-4000 PPM, and the first two cuttings were 3,000 to 8,000 PPMS. The first cutting at El Centro was increased from about 6,000 PPM nitrate to over 20,000, and the first cutting at Blythe ranged from 100 to 2500 PPM. Similarly, previous observations of nitrates as affected by N have show dramatic affects, causing sudangrass nitrates to range from 2,000 to 25,000 PPM nitrate (Sumner et al., 1968).

Many experts describe hay with less than 1,000 PPM as generally safe, and hay with less than 2,000 PPM as mostly safe except for consideration given to particular classes of livestock (pregnant animals, very young animals). It is possible to feed forage from the 2,000-4,000 PPM range, but the quantity should be limited and the ration fortified with energy, minerals and vitamin A. Concentrations of >4,000 PPM is often considered toxic and unsafe to feed. It should be noted that these 'threshold' levels are not universal, and opinions may vary widely as to acceptable levels of nitrate in forage. The acceptability of nitrates in diets is a complex trait with type of animal, acclimatization, health, water source, and total ration ingredients all important considerations.

However, many samples from this study shown concentrations >4,000. Since many of the exporters demand nitrates less than 1,000 PPM (and would prefer less than 750 PPM), this may be of concern, since even at 0 N fertilizers, some of the plots exhibited high nitrate contents. However, several points should be made. The first is that considerable transformation of nitrate may occur during the curing process. These

samples were taken directly from the field and oven dried, likely preventing substantial enzymatic transformation of plant cell nitrate to amino acids which would occur during an extended curing time. Secondly, absolute levels may differ according to method, making comparisons among hay lots more difficult. These two issues are subjects of importance for further study in the coming year.

Cardy meter readings for nitrate of the standing crop did respond to applications of N fertilizers (Figure 12). Cardy meter readings were somewhat successful at predicting relative changes in plant nitrate. The data in Figure 13 represents the relationship between the Cardy readings (X) for all values which are currently available (more sample results are pending at this writing). However, it is questionable as to whether the absolute values of Cardy meter readings or the relative readings will be helpful in the management of N fertilizers by growers. In this sample set, a negative bias (under-predicting the lab values) was seen, explaining 67% of the variation in lab nitrate values.

High nitrate values are clearly a hazard of sudangrass production, but not always clearly related to soil N values. Plant nitrate accumulation is also a function of temperature, stage of sample, drought stress, cold stress, and other factors. It is apparent from these studies that avoidance of high N applications is an important (but not the only) strategy for minimizing nitrates in forage. From the standpoint of fertilizer management, however, there is a clear incentive to minimize applications to the greatest extent possible.

Table 1. Value of Additional yield from each increment of N Fertilizer in Blythe and El Centro, 1997 and 1998 (seasonal totals). Assumptions: \$80/ton hay, \$30/lb N applied.

| Rate/Cutting(lb./a) | Blythe 97 | El Centro 97 | Blythe 98 | El Centro 98 |
|---------------------|-------------------|--------------|-----------|--------------|
| | -----\$/acre----- | | | |
| 35 | 73 | 31 | 110 | 164 |
| 70 | 103 | 3 | 142 | 72 |
| 105 | -27 | -61 | 116 | -39 |
| 140 | -97 | -29 | 23 | -19 |
| 210 | -19 | -132 | 45 | -109 |

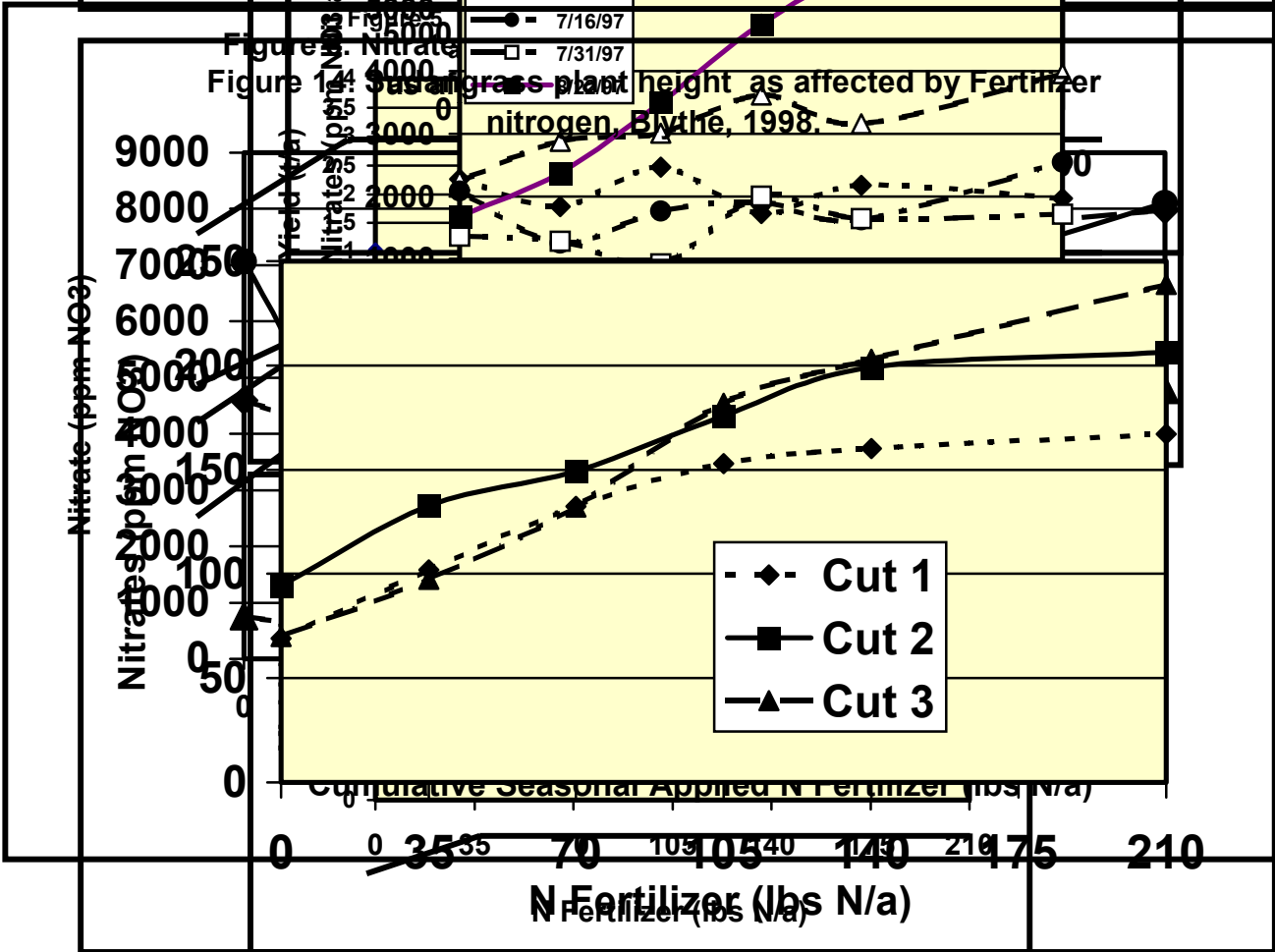
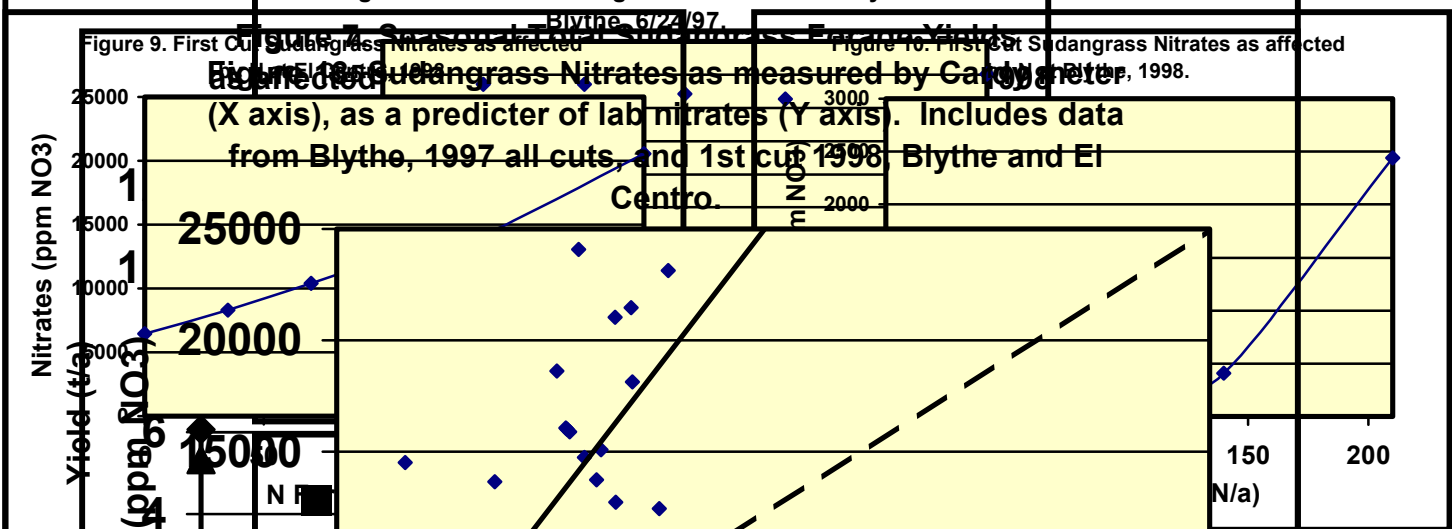
However, economics will likely cause growers to minimize fertilizer applications. Table 1 estimates the economic return of each increment of fertilizer applied. With the exception of Blythe, 1998, there was little indication that rates greater than 70 lbs/acre at each cutting would result in improved economic returns. At El Centro, although no significant effect of N on yield was found, some small benefit from the lower rates was seen. The Blythe 98 site was the most responsive of all sites, showing incremental economic returns all the way to the highest N rate.

SUMMARY

Sites varied in their N response, from no significant response at any N rate, to yield response to the highest rate per cutting (210 lbs/cut or 630 lbs/a per year N). Most

evidence indicates little chance of yield response at N applications greater than 70 lbs/acre per growth period (280 lbs N/year). Most sites indicated lower response in the first harvest, with a greater response in later cuttings, indicating that applications at the first growth period should be minimized to account for residual soil N. Nitrate concentrations in sudangrass forage were increased significantly in most cases by N applications, but fertilizers were not the only cause of high nitrates. Cardy meter (nitrate-specific electrode) readings explained 67% of the variation in plant nitrates in the samples analyzed to date, but the levels show a distinct negative bias, and some data sets showed a poor relationship between Cardy meter readings and plant nitrates. Future work should address issues of the causes of nitrate concentrations in sudangrass forage, and standardize nitrate methods.

Figure 3. First Cut Forage Yield as affected by N at



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